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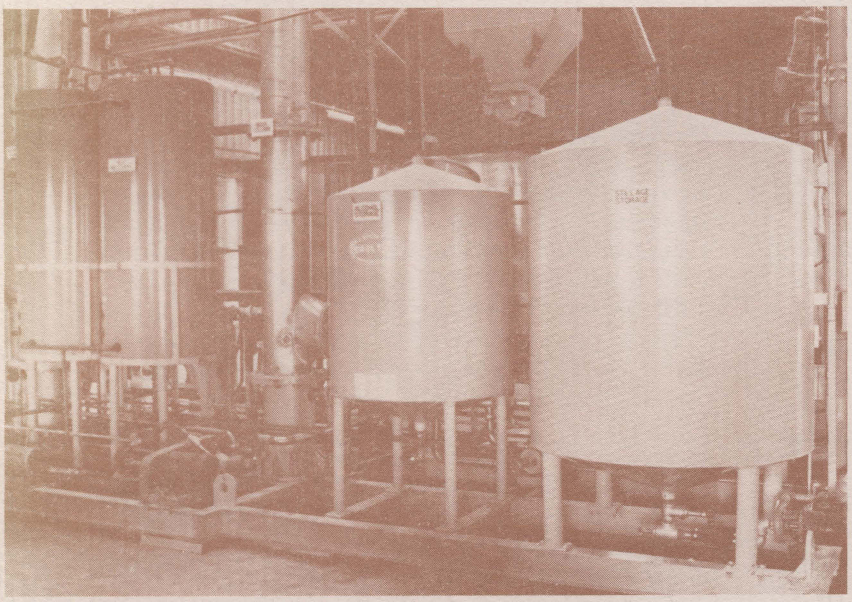
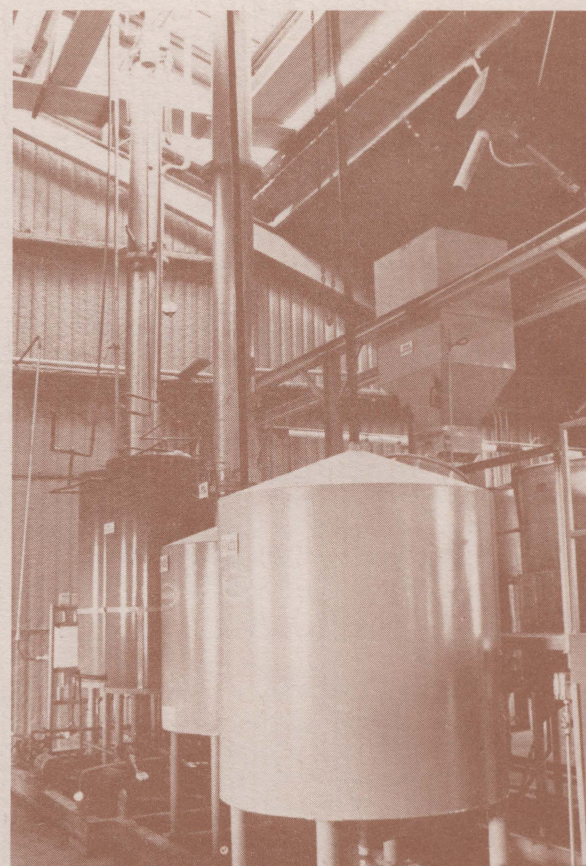
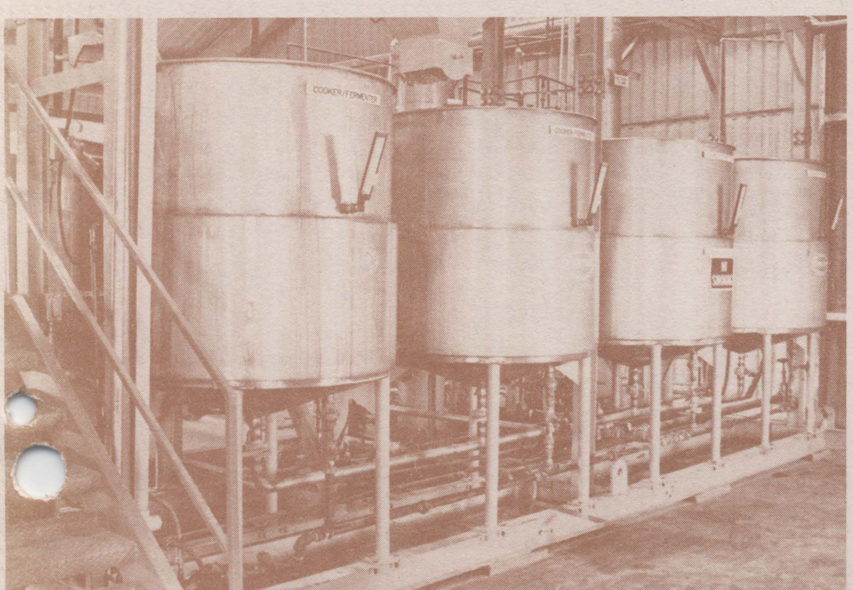


ETHYL ALCOHOL PRODUCTION





Operation of the Texas A&M University ethyl alcohol plant is an interdisciplinary project with support from the Texas Agricultural Extension Service, Texas Agricultural Experiment Station, Center for Energy and Mineral Resources, the Texas A&M University System; and the Texas Energy Development Fund of the Texas Energy and Natural Resources Advisory Council.

Ethyl Alcohol Production

Henry O'Neal*

The Agricultural Engineering Department at Texas A&M University has been operating a research and demonstration ethyl alcohol production plant since January 1981 as part of an alternate energy program. The plant is located on the Texas A&M University West Campus at the Agricultural Engineering Research Shop and is representative of a small, farm scale facility.

Alcohol Production Steps

Corn and grain sorghum are the main feedstocks used for alcohol production at the Texas A&M plant. The steps in production vary depending on the brand of enzymes used. Each enzyme manufacturer has slightly different temperature and water requirements to fit the activity of a particular enzyme. Any enzyme may be used but should be used according to the manufacturer's recommendations. A combination of enzymes from two different manufacturers has worked well at the Texas A&M plant.

The following general production steps are the ones presently used and may change with future production experience.

1. The grain is ground in a hammermill with a 1/8-inch screen. Each of the 350 gallon cooker-fermenter tanks normally handles a 12-1/2 bushel batch.

2. The ground grain is added to and mixed with 150 gallons of water (12 gallons per bushel) at 120 degrees F. This begins the cooking process, during which the grain mixture or mash is constantly agitated. A liquefying enzyme (Taka-Therm by Miles Laboratories Inc.) is added at the rate of 30 grams per 56 pounds of grain. The pH of the grain mash normally ranges from 6.0 to 6.4, which is within the optimum pH range of the liquefying enzyme (pH 5.5 to 7.0). The mash is then heated to 210 degrees F at a rate of about 1 degree per minute. The mash is held at this temperature for one hour. The heating and cooking is achieved by direct steam injection.

3. At the end of the cooking period, 62-1/2 gallons of cold water (5 gallons per bushel of grain) are added to begin cooling the mash to a temperature of 98 degrees F. The cooling process includes running cold water through a water jacket on the outside of the cooker, reducing the temperature about 1 degree F per minute. The pH of the mash is lowered to 5.0 to 5.4 during the cooling process (at 100 to 120 degrees F) by adding sulfuric acid.

4. A saccharifying enzyme (Gasolase by Biocon Inc.) is added at the rate of 12 grams per 56 pounds of grain. Distiller's yeast or baker's yeast (or a half-and-half mixture) is added at the rate of 1 pound per 300 gallons of mash. The enzyme and yeast are allowed to mix for 15 to 20 minutes before agitation is stopped.

5. The mash is then allowed to ferment at a temperature not to exceed 100 degrees F. In the Texas A&M plant, the cooker is also the fermenter. At temperatures of 94 to 98 degrees F, fermentation is complete in 2-3/4 to 3 days. The fermented mixture is known as beer.

6. The next step is to separate the ethyl alcohol from the beer using two 12-inch diameter plate distillation columns, each 20 feet in height. All of the fermented mash is put into the first column (beer column) with steam injected directly into the base of the column. A mixture of alcohol and water vapor is driven from the top of the beer column while grain and water residue (stillage) are removed from the bottom. The alcohol and water vapor then enter the bottom of the second column (rectifying column) where alcohol vapor is driven off at the top and condensed to yield liquid alcohol. The normal production proof of the Texas A&M University plant is 182 to 184.

7. The solid grain residues are separated from the stillage in an auger de-watering press. These solid residues (distiller's grains) leave the de-watering press at about 65 percent moisture with a yield of about 8 pounds of residue (dry weight basis) per bushel of original grain. These

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residues contain 27 to 28 percent protein. After removal of the distiller's grains, about 8 to 9 pounds of grain residue remain as solubles in the water.

Plant Operation Data

With corn and grain sorghum as the main feedstocks, the average yield at the Texas A&M plant is 2.6 gallons of 182 to 184 proof ethyl alcohol per bushel of corn and 2.5 gallons per bushel of grain sorghum. The equivalent for 200 proof alcohol would be 2.4 gallons per bushel of corn and 2.3 gallons per bushel of grain sorghum.

The average electricity, natural gas and water requirements of the plant for the production of 182 to 184 proof ethyl alcohol are listed in the following sections.

Electricity Use

Average electricity use to produce 182 to 184 proof ethyl alcohol from corn and grain sorghum is 0.7 kilowatt hours per gallon of alcohol produced. This includes grinding grain and running all plant motors. Electricity for lighting in the plant building is not included.

Natural Gas Use

Natural Gas Use per Gallon of Alcohol Produced

Cooking	25 cubic feet
Distilling	45 cubic feet
Total	70 cubic feet

This natural gas use is average for a production batch using 12 gallons of cooking water at 118 to 120 degrees F initially and an additional 5 gallons of cooling water per bushel of grain after cooking. Hot condenser water from a previous distillation is stored in tanks and used for cooking. Natural gas required for cooking increases 5 to 10 cubic feet per gallon of alcohol produced when the batch is started with cold water.

Using additional cooking and cooling water lowers the beer alcohol concentration and increases the amount of natural gas required for distillation by about 5 to 10 cubic feet per gallon of alcohol produced.

Water Use

Water Use per Gallon of Alcohol Produced

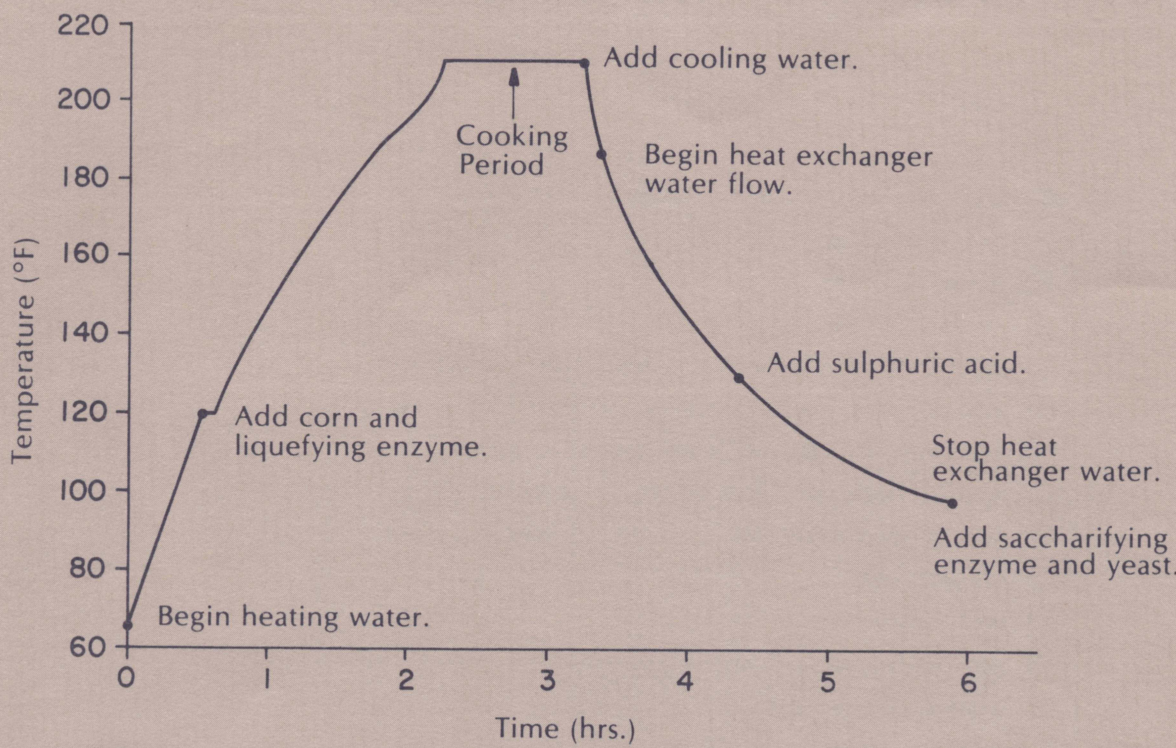
Cooking	
Added to grain (17 gallons/bushel)	7 gallons
Heat exchanger (cooling water jacket)	25 gallons
Boiler	2 gallons
Distilling	
Condenser cooling	5 gallons
Boiler	2 gallons
Total	41 gallons

At the Texas A&M plant, water used in the heat exchanger is disposed of as waste water. However, it could be stored, cooled and used again as cooling water for the heat exchanger. Heat-exchanger water use was determined from January through April production batches. Water use increases during summer months because of higher water temperatures. Also during hot weather, fermentation temperatures rise and cooling water is used in the heat exchanger to keep fermentation temperatures below 100 degrees F.

Cooling water in the condenser heats up as vaporized alcohol is condensed to liquid alcohol. This hot water is stored and used as cooking water in a successive batch. Condenser cooling-water use may also increase as water temperatures rise during hot weather.

Cooking and Distilling Logs

The following cooking and distilling logs show typical production batches for the Texas A&M plant. Also following is a plant process diagram.



Batch 29 Cooking and Fermenting Log

Corn	682 pounds (12.2 bushels)
Natural gas used	*Meter measures in increments of 100 cubic feet.*
Cooking	1,000 cubic feet (33 cubic feet/gallon of alcohol produced)
Boiler start up	100 cubic feet
TOTAL	1,100 cubic feet
Water used	
Cooking (12 gallons/bushel)	146 gallons
Cooling (4 gallons/bushel)	49 gallons
Heat exchanger (5.2 g.p.m. flow rate)	787 gallons (25.7 gallons/gallon of alcohol produced)
Boiler	51 gallons (1.7 gallons/gallon of alcohol produced)
Boiler start up	12 gallons
TOTAL	1,045 gallons

Fermenting time: 69 hours

Maximum fermenting temperature: 101° F after 24 hours

Temperature at end of fermenting period: 86° F

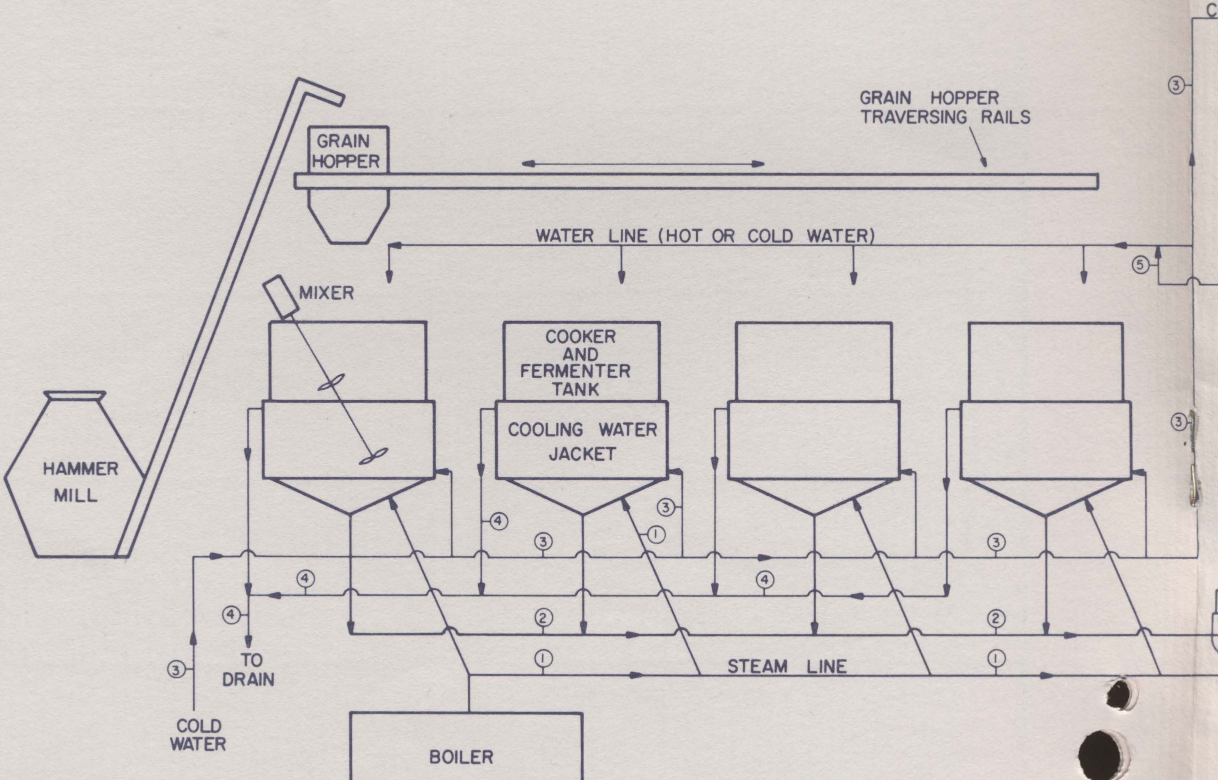
Enzymes:
- Liquefying (Taka-Therm manufacturered by Miles Laboratories Inc.)
- Saccharifying (Gasolase manufactured by Biocon Inc.)

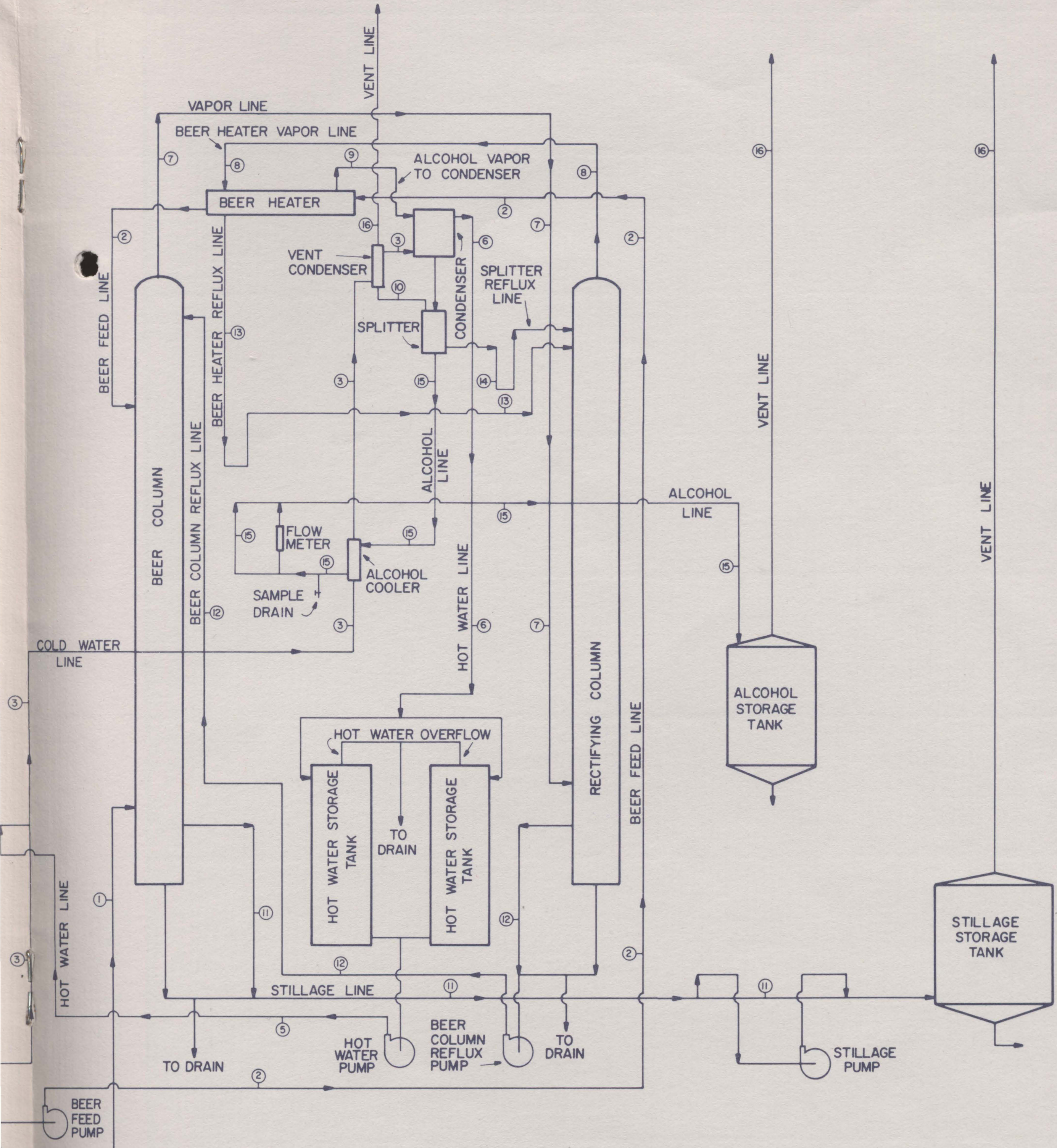
Yeast:
- Bakers
- Distillers (manufactured by Biocon Inc.)

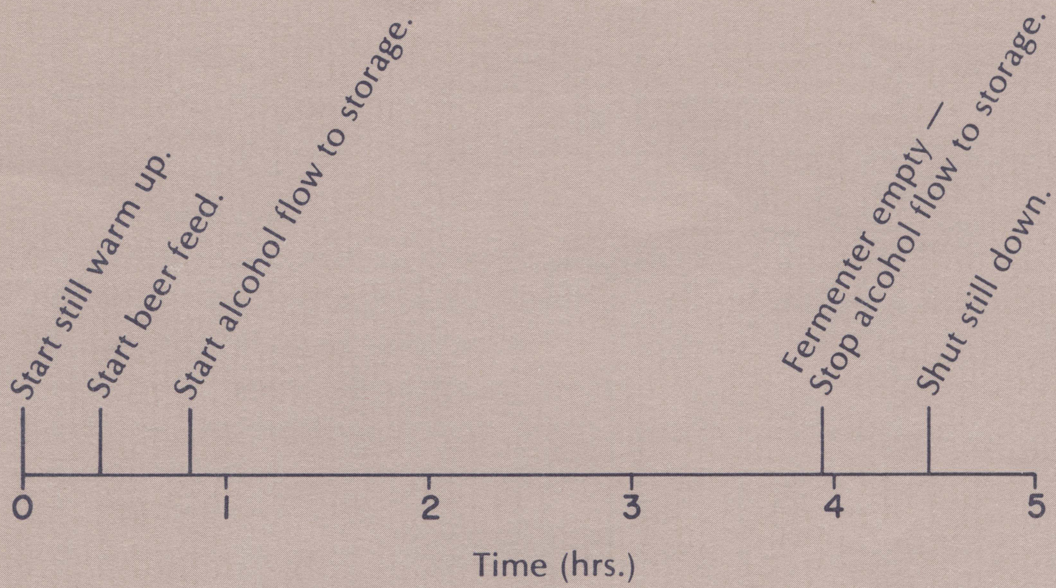
ETHYL ALCOHOL PROCESS DIAGRAM

LEGEND

(1) STEAM LINE
(2) BEER FEED LINE
(3) COLD WATER LINE
(4) WATER DRAIN LINE
(5) HOT WATER LINE
(6) HOT WATER LINE – CONDENSER TO HOT WATER STORAGE TANK
(7) ALCOHOL VAPOR LINE – BEER COLUMN TO RECTIFYING COLUMN
(8) ALCOHOL VAPOR LINE – RECTIFYING COLUMN TO BEER HEATER
(9) ALCOHOL VAPOR LINE – BEER HEATER TO CONDENSER
(10) ALCOHOL VAPOR/LIQUID LINE – SPLITTER TO VENT CONDENSER
(11) STILLAGE LINE
(12) BEER COLUMN REFLUX LINE
(13) BEER HEATER REFLUX LINE
(14) SPLITTER REFLUX LINE
(15) ALCOHOL LINE
(16) VENT LINE

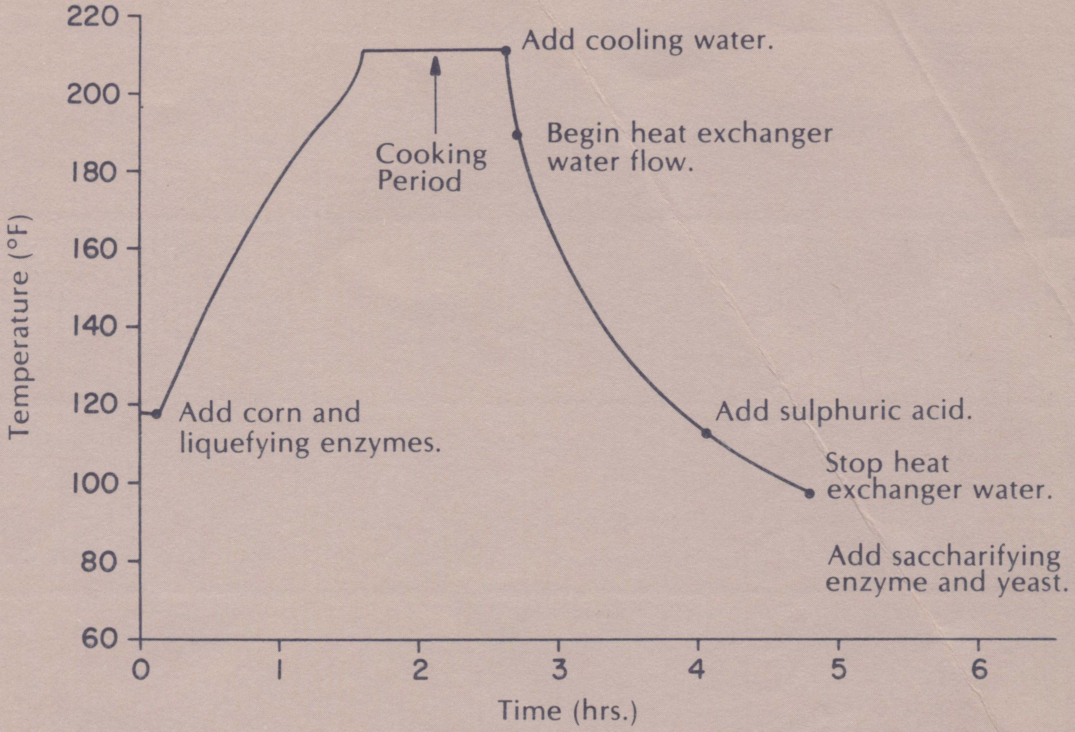



VENT LINE
VAPOR LINE
BEER HEATER VAPOR LINE
ALCOHOL VAPOR TO CONDENSER
BEER HEATER
VENT CONDENSER
CONDENSER
SPLITTER REFLUX LINE
SPLITTER
BEER FEED LINE
BEER HEATER REFLUX LINE
BEER COLUMN
BEER COLUMN REFLUX LINE
ALCOHOL LINE
FLOW METER
ALCOHOL COOLER
SAMPLE DRAIN
COLD WATER LINE
HOT WATER LINE
RECTIFYING COLUMN
BEER FEED LINE
ALCOHOL LINE
ALCOHOL STORAGE TANK
VENT LINE
VENT LINE
HOT WATER OVERFLOW
HOT WATER STORAGE TANK
TO DRAIN
HOT WATER STORAGE TANK
STILLAGE LINE
TO DRAIN
HOT WATER PUMP
BEER COLUMN REFLUX PUMP
TO DRAIN
STILLAGE PUMP
STILLAGE STORAGE TANK
HOT WATER LINE
BEER FEED PUMP



Batch 29 Distilling Log

Corn	682 pounds (12.2 bushels)
Beer	281 gallons
Alcohol into storage tank	30.6 gallons at 183 proof
Alcohol (still clean out)	4.8 gallons at 38 proof = 1.0 gallon at 183 proof
Total alcohol produced	31.6 gallons at 183 proof
Corn production rate	2.6 gallons/bushel at 183 proof; 2.4 gallons/bushel at 200 proof equivalent
Distilling time (30.6 gallons alcohol)	3 hours, 03 minutes
Average distilling rate	10 gallons/hour
Natural gas used	*Meter measures in increments of 100 cubic feet*
Distilling	1,200 cubic feet (39 cubic feet/gallon of alcohol produced)
Still warm-up and clean-out	600 cubic feet
TOTAL	1,800 cubic feet
Water used	
Condenser	199 gallons (6.5 gallons/gallon of alcohol produced)
Boiler	73 gallons (2.4 gallons/gallon of alcohol produced)
Still warm-up and clean-up	262 gallons
TOTAL	534 gallons



Batch 30 Cooking and Fermenting Log

Corn	689 pounds (12.3 bushels)
Natural gas used	*Meter measures in increments of 100 cubic feet*
Cooking	800 cubic feet (26 cubic feet/gallon of alcohol produced)
Boiler start up	0
TOTAL	800 cubic feet
Water used	
Cooking (12 gallons/bushel)	148 gallons
Cooling (5 gallons/bushel)	62 gallons
Heat exchanger (6.7 g.p.m. flow rate)	837 gallons (27.4 gallons/gallon of alcohol produced)
Boiler	35 gallons (1.1 gallons/gallon of alcohol produced)
Boiler start up	12 gallons
TOTAL	1,094 gallons

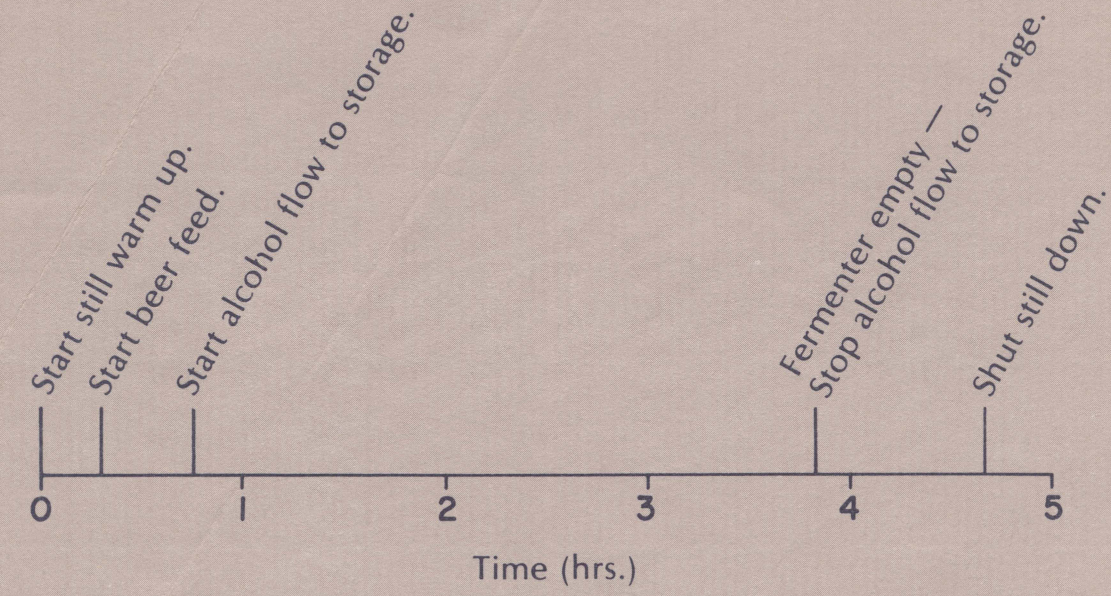
Fermenting time: 68 hours

Maximum fermenting temperature: 99° F after 24 hours

Temperature at end of fermenting period: 86° F

Enzymes:
- Liquefying (Taka-Therm manufacturered by Miles Laboratories Inc.)
- Saccharifying (Gasolase manufactured by Biocon Inc.)

Yeast:
- Bakers
- Distillers (manufactured by Biocon Inc.)



Batch 30 Distilling Log

Corn	689 pounds (12.3 bushels)
Beer	285 gallons
Alcohol into storage tank	30.6 gallons at 183 proof
Alcohol (still clean out)	7.4 gallons at 39 proof = 1.6 gallons at 183 proof
Total alcohol produced	32.2 gallons at 183 proof
Corn production	2.6 gallons/bushel at 183 proof; 2.4 gallons/bushel at 200 proof equivalent
Distilling time (30.6 gallons alcohol)	3 hours, 08 minutes
Average distilling rate	9.8 gallons/hour
Natural gas used	*Meter measures in increments of 100 cubic feet*
Distilling	1,400 cubic feet (46 cubic feet/gallon of alcohol produced)
Still warm-up and clean-out	600 cubic feet
TOTAL	2,000 cubic feet
Water used	
Condenser	202 gallons (6.6 gallons/gallon of alcohol produced)
Boiler	70 gallons (2.3 gallons/gallon of alcohol produced)
Still warm-up and clean-up	318 gallons
TOTAL	590 gallons

Editor: Suzanne Black, Extension communications specialist, The Texas A&M University System.

Cooperative Extension Work in Agriculture and Home Economics, The Texas A&M University System and the United States Department of Agriculture cooperating. Distributed in furtherance of the Acts of Congress of May 8, 1914, as amended, and June 30, 1914.
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